RESEARCH AND DEVELOPMENT OF COMMERCIAL LIDAR SYSTEMS IN ROMANIA: CRITICAL REVIEW OF THE ESYRO LIDAR SYSTEMS DEVELOPED BY SC ENVIROSCOPY SRL (ESYRO)

Marius Mihai Cazacu[1, 2, 3], Ovidiu Tudose[4], Dragos Balanici[1] and Ioan Balin[1]

*[1] SC EnviroScopY SRL, Iasi - Romania, *ioan.balin@enviroscopy.com*
[2]Gheorghe Asachi Technical University of Iasi, Department of Physics, 700050 Iasi, Romania
[3]Alexandru Ioan Cuza University of Iasi, Faculty of Physics, Atmosphere Optics, Spectroscopy and Lasers Laboratory, 700506 Iasi, Romania
[4]SC Inoesy SRL, Iasi - Romania

ABSTRACT

This paper is shortly presenting the two basic lidar system configurations respectively a micro-lidar and a multi-wavelength lidar systems developed by SC EnviroScopY SRL (**ESYRO**) from Iasi – Romania in the last decade. Furthermore in addition to the comparative analysis of the two technical configurations the examples of various tests and the capability of the two systems to perform are here presented. Measurements samples of aerosols, clouds, PBL, depolarization and Saharan dust are also illustrated.

1 INTRODUCTION

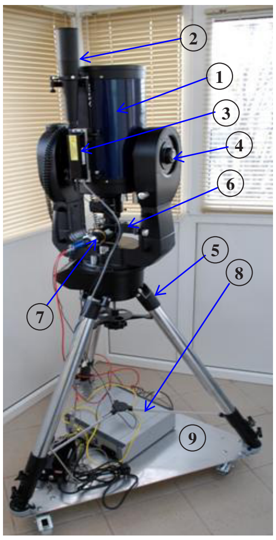
SC EnviroScopY SRL starts from its creation as start-up in 2006 to develop commercial aerosols lidar systems in Romania. According to size, the atmospheric aerosols have a large range, from nanometric particles (a couple of molecules) to particles larger than 10 µm. Aerosols influence the air quality and visibility, the net heat balance received by Earth's crust directly by reflecting the solar radiation back into space and indirectly by modifying the solar radiation absorption and reflection coefficients of the various cloud formations [5, 7]. Therefore, vertically measurements by lidars of physical and optical parameters of the aerosols are still of great interest. In addition the vertically monitoring of regional air pollution in order to complement the ground-based stations is nowadays clearly confirmed both by the key information concerning the atmospheric dynamics (as planetary boundary layer height and its variability) and the regional or long-range transport aerosols load estimation. Furthermore, the interaction between the aerosols (regional/global) as a trigger of regional pollution and meteorology (i.e. extreme events as hail and strong thunderstorms) is still not well known and difficult to assess without high-resolution fast atmospheric information [1].

In this context, from 2010, a new lidar network at Romanian national level was initiated under the development in the framework of Romanian LIdar NETwork (ROLINET) research project. One year later, the Romanian Atmospheric 3D research Observatory – RADO was founded. RADO [13] is a distributed atmospheric research infrastructure based on the collaboration between: National Institute of R&D for Optoelectronics (INOE), "Babes-Bolyai" University of Cluj-Napoca (UBB), "Alexandru Ioan Cuza" University of Iasi (UAIC), "Politehnica" University of Timisoara (UPT), University of Bucharest (UB) and National Administration for Meteorology (ANM) (RADO - 2015). Numerous coordinated experimental campaigns within Observation Network that is based on 5 existing lidar stations, which operate as the ROLINET, occurred [3, 4, 8]. Four of them are equipped with elastic backscatter lidars, having a dynamic range from 500 m to 15 km and a spatial resolution of 3.75 m and a multi-wavelength Raman lidar (3 elastic + 2 Nitrogen Raman + 1 water vapor channels) that is used at the INOE coordinator site, along with a tropospheric ozone lidar. All stations operate AERONET sunphotometers and ground-level in situ instruments, such as particle counters, gas analysers and weather stations in order to complement lidar observations. ESYRO LIDAR observations combined with RADAR data may help into the improvement of efficiency of anti-hail active intervention with AgI pyrotechnic charges i.e LIRA national project (2014-2015) coordinate by ESYRO in Romania, *PNCDI II – Contract No. 144 /2014* [14].

2 ESYRO LIDAR systems

2.1 The ESYRO microLIDAR system

The ESYRO microlidar system (Fig.1) transmitter is based on micropulse class 3B laser emitting at 532 nm ±0.1 nm. The pulse rate frequency is at 7.2 kHz and the pulse duration is 0.5 - 1ns with energy of 3μJ /pulse. The average power is about 30mW but the pulse peak power is around 6kW. The laser beam of 0.2-0.5 mm diameter is 20x expanded in order to reduce the beam divergence to 2-4 mrad. The microlidar receiver is based on a Cassegrain 20 cm telescope of 2 m focal distance and 3D scan available on which the transmitter module (laser + beam expander) is mounted. The lidar signal acquisition is made by an opto-mechanical detection module which is composed by a variable diaphragm, collimation lens and an interferential filter. This module is coupled with a photomultiplier operating in photon counting mode. The data acquisition is due to a high-speed electronic time of fly module triggered by a photodiode. This detection setup is assuring 3.75 m spatial resolution. The data treatment is computer assisted by labVIEW-dedicated routines for data acquisition alignment, dead time correction, SNR analysis, averaging, PBL (Planetary Boundary Layer) height determination and more.



(1) Astronomic Telescope
(2) Beam expander
(3) MicroPuls Laser
(4) 3D Mount
(5) Telescope tripod
(6) Opto – mechanical module
(7) Photodetector
(8) Acquisition module
(9) Transport platform

Figure 1: The microLIDAR system setup

The system is installed on a mobile platform based on a tripod. These system performances are comparable with the microlidars systems presented in [6, 12].

2.2 The ESYRO ESYLIDAR system

The new ESYLIDAR system designed as being a modular system, mobile, easy technically upgradable (multi-angle, multi-channels) for various applications, is used at the Iasi, Cluj-Napoca and Timisoara monitoring sites. The first version was based on a coaxial UV (355 nm), VIS (532 nm) and NIR (1064 nm) emission of a Nd:YAG laser with a variable repetition rate up to 30 Hz. The initial divergence of the 6 mm laser beam of 0.75 mrad was 5 times improved, by using a 3λ UV-VIS-NIR beam expander resulting in a beam of 30 mm diameter and a final divergence of 0.15 mrad [2, 10]. The ESYLIDAR receiver is based on a Newtonian configuration telescope being equipped with a 406 mm diameter primary mirror and a combined focal length of 1829 mm. ESYLIDAR system is presented in [9].

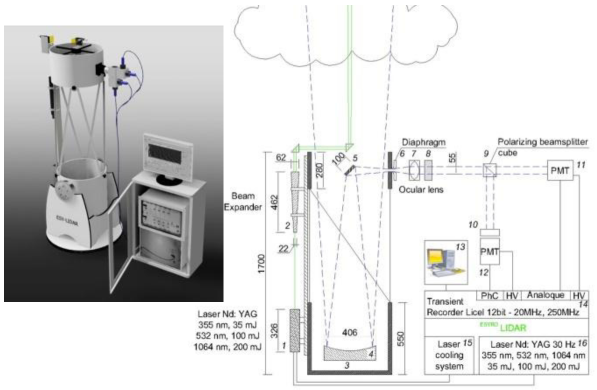


Figure 2: Schematic overview of the on axis ESYLidar system configuration: 1. Laser source Nd:YAG, 2. Beam expander, 3. Newtonian telescope, 4. Main telescope mirror, 5. Secondary telescope mirror, 6. Adjustable circular diaphragm, 7. Eye-piece, 8. Interference filters, 9. Polarizing beam splitter cube, 10. Optical filter, 11. Photomultiplier (in analog regime), 12. Photomultiplier (in photon-counting mode), 13. Computer for data analysis, 14. Acquisition board, and analog to digital convertor 15. Laser cooling unit, 16. Laser power

The detection module is further equipped with a lens assembly, filters and diaphragms which limit the acceptable spectrum, focus and select the reflected spectrum reaching the photomultipliers to make the most out of the useful signal produces by the laser-matter interaction [2, 9]. All resulting optical parameters were used in the final technical configuration of the on-axis lidar system that is represented in Fig.2.

The upgraded version was initiated to improve the fixation/alignment system by decreasing the distance between the main optical axis of the emission module and the main axis of the telescope (from the initial 360 mm to 320 mm). This reduced distance changes the overlap factor of the lidar system, factor describing the overlapping radiation ratio at emission and reception. The circular diaphragm located in the reception module can be reduced in size during sunny and bright days (necessary to maintain a good signal to noise ratio at the) and to maintain the photomultipliers in the linear response region for the wavelength of interest. By modifying the circular diaphragm, the overlapping factor is changing. To preserve the correct lidar signal the declination angle has to be adjusted. Accordingly, for a variation of the diameter of the diaphragm from 12 mm to 3 mm, the declination angle has to be changed from -0.5 mrad to 0.35 mrad (the minus sign denotes the declination orientation), thus the altitude where the overlapping factor becomes 1 can vary between 700 and 950 m. This system is comparable with one presented in [1].

4 MEASUREMENT SAMPLES

A RCS (range corrected signal) obtained with the ^{micro}LIDAR system for more than 2h of continuous measurements is shown in Fig.3.

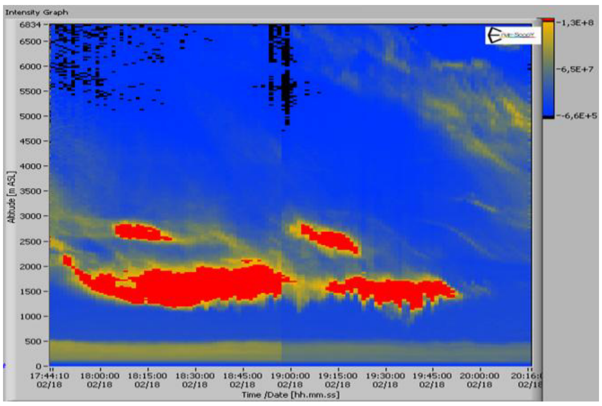


Figure 3: Sample of RCS from ^{micro}LIDAR data

In addition on the alignment stability we noticed the system is able to detect simultaneously a very low level of PBL winter time inversion at 500 m altitude, a complex group of tropospheric clouds from 1000 to 3000 m and some cirrus clouds at 6500 -7000 km with 7.5m spatial resolution. More results analysis are presented in [2].

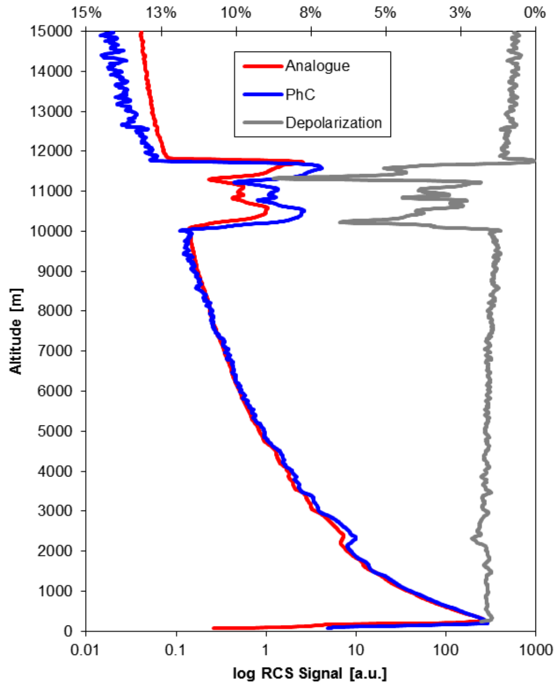


Figure 4: Sample of RCS from ^{ESY}LIDAR data [nighttime profile, 7.5 m spatial resolution, 1 min integration time]

A sample measurement obtained with ^{ESY}LIDAR system is shown in Fig.4. We can notice the 532 nm two channels (A for elastic direct signal and PhC for cross depolarization signal) as well as the depolarization ratio profile. ^{ESY}LIDAR may be considered as a powerful lidar system able to profile the atmosphere up to lower stratosphere i.e.15 km (day) - 20 km (night) and a high spatial (7.5 m) and temporal (1 min) resolution. In Fig. 4 from 10 to 12km tropospheric cirrus clouds are detected with ice crystal contents up to 8%. Thus one may also use this system for Saharan dust and o volcano ash plumes monitoring. Typically, the lidar data are correlated with complementary techniques such as the AERONET sunphotometers, the Calipso lidar system, and with theoretical models (DREAM, HYSPLIT). AErosol RObotic NETwork (AERONET) is a NASA network for monitoring and characterizing atmospheric aerosols by ground-based sun photometer. Beginning with the 7th of May 2012, the monitoring station LOA-SL in Iasi, Romania (Lat: 47.19° N, Long: 27.55° E) is active in this network providing quantitative values for various types of aerosols. Based on this synergy many measurements campaigns and case studies were performed as shown in the [2–4, 8–11].

5 CONCLUSIONS

Two operational lidar systems, respectively a ^{micro}LIDAR and the ^{ESY}LIDAR, developed by SC EnviroScopY SRL (ESYRO) based in Iasi, RO were presented together with sample relevant measurement tests. A ^{micro}LIDAR system is still in use by National Meterological Service while ^{ESY}LIDAR systems are operating at UBB, UAIC and UPT universities. A depolarization version of ^{ESY}LIDAR system was operated during LIRA project 2014-2016 by ESYRO [14]. The performances of these two systems are comparable with the up to date academic systems but they are not enough designed yet to be commercially rentable and more efforts are ongoing to improve them.

ACKNOWLEDGEMENTS

Romanian Research Ministry (A.N.C.S.I.) for co-founding the research and development and to academic research partners as INOE, UAIC, UPT, UB and UBB.

References

[1] Balin, I., 2004: Measurement and analysis of aerosols, cirrus-contrails, water vapor and temperature in the upper troposphere with the Jungfraujoch LIDAR system. Thèse École polytechnique fédérale de Lausanne, no 2975.

[2] Cazacu, M.M., 2010: Contributions to the implementation of the first national LIDAR network for atmospheric aerosols optical characterization. PhD Thesis, Alexandru Ioan Cuza University of Iasi, Romania.

[3] Cazacu, M.M., Timofte, A., Talianu, C., Nicolae, D., Danila, M.N., Unga, F., Dimitriu, D.G., Gurlui, S., 2012: Grimsvotn Volcano: atmospheric volcanic ash cloud investigations, modelling-forecast and experimental environmental approach upon the Romanian area. *J. Optoelectron. Adv. Mater.* **14** (5–6), S. 517–522.

[4] Papayannis, A., Nicolae, D., Kokkalis, P., Binietoglou, I., Talianu, C., Belegante, L., Tsaknakis, G., Cazacu, M.M., Vetres, I., Ilic, L., 2014: Optical, size and mass properties of mixed type aerosols in Greece and Romania as observed by synergy of lidar and sunphotometers in combination with model simulations: A case study. *Sci. Total Environ.* **500–501** S. 277–294.

[5] Seinfeld, J.H., Pandis, S.N., 2006: Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 2nd Edition - John Wiley & Sons, Inc. New Jersey.

[6] Spinhirne, J.D., 1993: Micro Pulse Lidar. *IEEE Trans. Geosci. Remote Sens.* **31** (1), S. 48–55.

[7] Stefan, S., Nicolae, D., Caian, M., 2008: Secretele aerosolului atmosferic în lumina laserilor. Ed. Ars Docendi.

[8] Timofte, A., Cazacu, M.M., Radulescu, R., Belegante, L., Dimitriu, D.G., Gurlui, S., 2011: Romanian lidar investigation of the Eyjafjallajokull volcanic ash. *Environ. Eng. Manag. J.* **10** (1), S. 91–97.

[9] Tudose, O.-G., 2013: Contributions to the study of atmospheric aerosols optical properties using remote sensing techniques. PhD Thesis, Alexandru Ioan Cuza University of Iasi, Romania.

[10] Tudose, O.-G., Cazacu, M.-M., Timofte, A., Balin, I., 2011: ESYROLIDAR system developments for troposphere monitoring of aerosols and clouds properties. *Proc. SPIE.* **8177** S. 817716-817716–10.

[11] Unga, F., Cazacu, M.M., Timofte, A., Bostan, D., Mortier, A., Dimitriu, D.G., Gurlui, S., Goloub, P., 2013: Study of tropospheric aerosol over Iasi , Romania , during summer of 2012. *Environ. Eng. Manag. J.* **12** (2), S. 297–303.

[12] Cheng, Y.S.A., Guo, Y., Zhu, J., 2004: Micropulse lidar system. *United States Pat. no. 6.717.655.*

[13] 2015: RADO - Romanian Atmospheric 3D research Observatory http://environment.inoe.ro/category/66/rado.

[14] LIRA: http://lira.inoe.ro/?lang=en